Proceedings of the DIS'2004, Štrbské Pleso, Slovakia

SINGLE-SPIN TRANSVERSE ASYMMETRY IN NEUTRAL PION AND CHARGED HADRON PRODUCTION AT PHENIX

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The PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) has measured the single-spin transverse asymmetry (A_N) for neutral pion and non-identified charged hadron production at $x_F \sim 0$ over a transverse momentum range of ~ 0.5 to 5.0 GeV/c from polarized proton-proton interactions at a center of mass energy ($\sqrt{s}$) of 200 GeV. The asymmetries observed are consistent with zero.

1 Introduction

Contrary to original expectations from perturbative quantum chromodynamics (pQCD) [1], large transverse single-spin asymmetries have been observed in a number of experiments [2,3,4], ranging in energy from $\sqrt{s}$ = 20-200 GeV. The large asymmetries seen have stimulated more careful study by the theoretical community of polarized cross sections, in particular their dependence on the intrinsic transverse momentum of the partons (k_T) (see e.g. [5]).

Over the years, a number of models based on pQCD have been developed to predict these k_T dependencies and to explain the observed asymmetries. Among these models are the Sivers effect [6], transversity and the Collins effect [7], and various models which attribute the observed asymmetries to higher-twist contributions (see e.g. [8]).

The unpolarized cross sections for mid-rapidity production as well as forward production of neutral pions have been measured in 200-GeV proton-proton collisions at RHIC and have been found to agree well with next-to-leading order (NLO) pQCD calculations [9,4]. This agreement indicates that NLO pQCD will be applicable in interpreting polarized data from RHIC as well and provides a solid theoretical foundation for the spin physics program.

The analyzing power (A_N) is the azimuthal asymmetry in particle production by a transversely polarized beam on an unpolarized target. Experimentally, the analyzing power on the left side of the beam is given by

$$A_N = \frac{1}{P_{beam}} \frac{1}{<|cos\phi|>} \frac{N^{\uparrow} - RN^{\downarrow}}{N^{\uparrow} + RN^{\downarrow}} \tag{1}$$

where P_{beam} is the beam polarization, $<|cos\phi|>= \frac{\sum_{j=1}^{N} |cos\phi_j|}{N}$ a correction for the azimuthal detector acceptance, $N^{\uparrow}$ ($N^{\downarrow}$) the experimental yield from up- (down-)

polarized bunches, and $R = \frac{L^{\uparrow}}{L^{\downarrow}}$ the relative luminosity of and up- and down-polarized bunches.

2 Data and Analysis

The data analyzed were taken during the first polarized proton run at RHIC (2001-2), in which approximately 0.15 pb^{-1} were collected at PHENIX. The stable spin direction of the protons is vertical. Both beams were polarized, and then single-spin analyses were performed by averaging over the spin states of one beam. The average beam polarization was 15%, measured using proton-carbon elastic scattering in the coulomb nuclear interference (CNI) region [10]. The analyzing power was measured at a beam energy of 22 GeV to within ±30% [11] and is here estimated to be the same at 100 GeV.

In PHENIX, a collision trigger is provided by the coincidence of signals in two beam-beam counters (BBCs) [12]. Events within 75 cm of the nominal interaction point were taken as minimum bias (MB) events. The BBCs were also used to determine the relative luminosity between bunches of opposite polarization sign.

Neutral pions were reconstructed via their decay to two photons using finely granulated electromagnetic calorimeters [13]. A high-energy photon trigger with an energy threshold of approximately 0.8 GeV, in coincidence with the MB trigger, was used to collect the neutral pion data [9]. Neutral pion yields were extracted by integrating the two-photon invariant mass spectrum from 0.12-0.16 GeV/c^2, as indicated by the black band in Figure 1. The contribution from combinatorial background ranged from 58% to 9% in the lowest and highest transverse momentum bins. The contribution to the asymmetry by the combinatorial background under the peak was estimated by calculating the asymmetry of the grey bands on both sides of the signal (Fig. 1). The asymmetry under the peak was then corrected using

$$A_N^{\pi^0} = \frac{A_N - rA_N^{BG}}{1-r} \quad \sigma_{A_N^{\pi^0}} = \frac{\sqrt{\sigma^2_{A_N} + r^2\sigma^2_{A_N^{BG}}}}{1-r} \tag{2}$$

where r is the fraction of combinatorial background under the peak.

Tracks of charged hadrons were reconstructed using a drift chamber and one of several pad chambers [14] as well as the BBCs to determine the collision vertex. In order to eliminate electrons from photon conversions, it was required that there be no hit in the ring-imaging Cherenkov detector (RICH) [15]. The electron contamination in the final data sample was less than 1%. The decay background from long-lived particles could not be eliminated. However, because these tracks have incorrectly reconstructed momentum, the analyzing power for these tracks is p_T independent.

The asymmetry was determined for each fill using Eq. 1, then fit to a constant across all fills. The χ^2 of the fit and a "bunch-shuffling" technique were used to check the uncertainties assigned to the asymmetry. In the bunch shuffling technique, the spin direction of each bunch is randomly reassigned and A_N is subsequently recalculated. This procedure was repeated many times (1000), and the widths of the

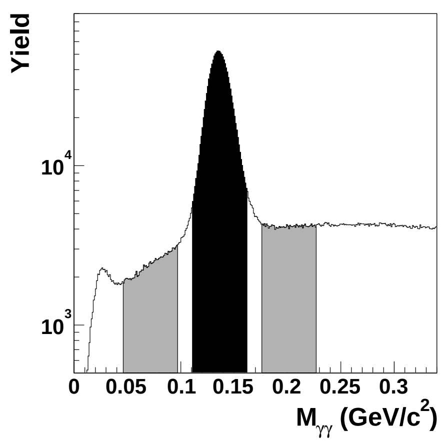

Figure 1. Two-photon invariant mass distribution. The analyzing power was first calculated for the region including both signal and background under the π^0 mass peak, shown in black. Then the contribution of the combinatorial background to the asymmetry under the peak was estimated and corrected for using the grey sidebands.

resulting asymmetry distributions were no larger than the statistical uncertainties assigned to the physical asymmetries, indicating that all non-correlated bunch-to-bunch and fill-to-fill systematic uncertainties were much smaller than the statistical uncertainties.

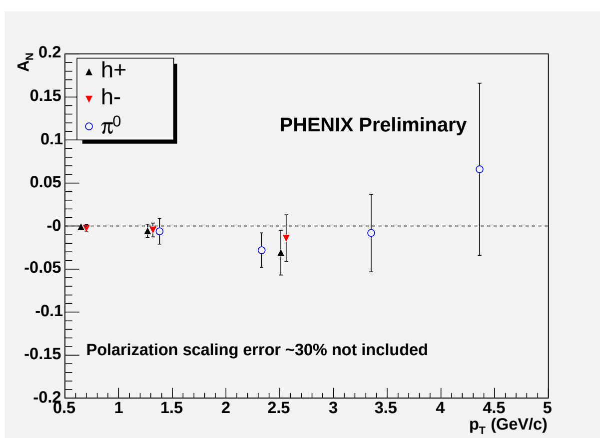

Figure 2. Transverse single-spin asymmetries for inclusive charged hadrons and neutral pions.

The resulting asymmetries are shown in Fig. 2. Systematic uncertainties are

negligible compared to the statistical uncertainties given. A total scale uncertainty of approximately ±30% from the measurement of the beam polarization is not shown.

3 Conclusions

The transverse single-spin asymmetries observed for production of both neutral pions and inclusive charged hadrons at $x_F \sim 0$ are consistent with zero over the measured transverse momentum range. A small asymmetry in this kinematic region follows the trend of previous results, which indicate a decreasing asymmetry at decreasing x_F [16,4]. As a significant fraction of particle production in this kinematic region comes from gluon scattering, any contribution to the asymmetry from transversity and the Collins effect would be suppressed, while contributions from the Sivers effect or other mechanisms would remain a possibility. Further theoretical study of the results will have to be performed in order to interpret their full implications for the transverse spin structure of the proton.

Acknowledgements

PHENIX acknowledges support from the Department of Energy and NSF (U.S.A.), MEXT and JSPS (Japan), CNPq and FAPESP (Brazil), NSFC (China), CNRS-IN2P3 and CEA (France), BMBF, DAAD, and AvH (Germany), OTKA (Hungary), DAE and DST (India), ISF (Israel), KRF and CHEP (Korea), RAS, RMAE, and RMS (Russia), VR and KAW (Sweden), U.S.CRDF for the FSU, US-Hungarian NSF-OTKA-MTA, and US-Israel BSF.

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